SECTION 7.0
RIPARIAN FUNCTION

7.1 INTRODUCTION

The riparian function analysis was conducted on the Acme WAU following methods and procedures presented in the Manual (Washington Forest Practices Board 1994). The analysis was conducted on the mainstem and major tributaries to the South Fork Nooksack River, including Black Slough; Caron Road, Falls, Gravel Pit, Hardscrabble, Jones, Landing Strip, McCarty, Mosquito Lake Road, Standard, Sygitowicz, Van Zandt and Williams Lake Creeks; and several tributaries to these streams. This analysis was conducted to determine near- and long-term prospects for large woody debris (LWD) inputs to the stream network and to assess levels of riparian shade and other factors influencing stream temperature.

7.2 LARGE WOODY DEBRIS

LWD is an important structural element in forest streams of the Pacific Northwest. In-channel woody debris influences channel shape and sediment storage, dissipates stream energy, provides a substrate and food source for stream invertebrates, and influences fish habitat in various other ways (Bilby and Ward 1989, 1991; Bisson et al. 1987). The purpose of this analysis is to determine "the condition of the riparian zone relative to its ability to supply large woody debris to the stream" (Manual, page 9-4).

7.2.1 Methods

LWD recruitment was assessed by examining 1991 black and white aerial photographs (scale 1:12000, stored at headquarters of the Trillium Corporation) to determine the type, size and density of trees growing within a 66 foot wide riparian corridor along all fish-bearing streams. These waters included all Type 1 through 3 streams. Based on observed differences in tree type, size and density, this stream network was divided into riparian condition unit (RCU) lengths of 1,000 feet or more.

Within each RCU, tree type was classified as "coniferous" (>70 percent conifer canopy), "deciduous" (>70 percent hardwood canopy), or "mixed" (intermediate compositions). Tree size was classified as "young" (<12 inches diameter at breast height [DBH]), "mature" (12-20 inches DBH), or "old" (>20 inches DBH). Tree density was considered "sparse" if more than one-third of the ground was exposed in aerial photographs. Otherwise, it was considered "dense."

All RCUs were categorized by LWD recruitment potential based upon the combination of type, size and density characteristics of each RCU. Each RCU was determined to have "good", "fair" or "poor" potential for LWD recruitment.

Some RCU's were assigned indeterminate ratings during the aerial photograph review. These RCU's required field investigation to determine LWD recruitment potential. Field investigation also served to verify initial findings for selected streams representing a range of tree type, size and density estimates. Such verification was necessary to determine our level of confidence in the aerial photograph analysis. Field surveys were conducted following procedures outlined in the Manual. The Manual analysis procedure was modified in three ways:

1. Qualitative observations were recorded regarding land use (agricultural or timber production), evidence of human manipulation of the channel, and presence of wetland habitat.

2. Field forms were completed and supporting photographs were taken for each reach surveyed (Appendix 7-1).

3. Results are not classified according to channel segment type. The primary factor influencing riparian LWD recruitment in this WAU is not channel type, but land use. Agricultural lands primarily (90 percent) have poor LWD recruitment potential and include nearly all of channel segments 1, 2, 3 and 4. Forested lands primarily (86 percent) have fair or good LWD recruitment potential and include all of channel segments 7 and 8. In channel segments 5 and 6, forested reaches tend to have fair or good LWD recruitment and agricultural reaches tend to have poor LWD recruitment. Thus, classification of LWD recruitment according to channel segment would present a misleading picture of the distribution and causes of poor LWD recruitment.

Most indeterminate ratings arose because of uncertainty whether to classify tree type as mixed or deciduous. These RCU's consisted of narrow bands of deciduous forest bordering streams in agricultural lands along Type 3 tributaries of the South Fork. After field-verification, all indeterminate ratings were resolved and assigned an LWD recruitment potential rating.

The analysis also attempted to clarify the history of the WAU, in order to better understand processes that have caused habitat degradation and management responses necessary to mitigate such degradation. This analysis included examination of early aerial photography (Army Map Service 1944), an early channel survey (State of Washington Department of Conservation and Development 1938), the original government land office survey (Iverson 1885), and the published reminiscences of pioneers in the area (Hawley 1945, Jeffcott 1949), as well as examination of current soil maps for the WAU (Goldin 1992).

Product	Location
Map D-1	Figure 7-1
Worksheet D-1	Data in Tables 7-1 and 7-3
Map D-2	Figure 7-2
Worksheet D-2	Data in Table 7-3
Map D-3	Figure 7-3
Worksheet D-3	Not included
the shade Map D-3	Figure 7-4
the shade Worksheet D-3	Data in Table 7-4
Map D-4	Figure 7-4
Response to LWD critical question	Section 7.2.2
Response to shade critical question	Section 7.3.2
Airphoto data	Section 7.2.1
Describe historical sources	Sections 7.2.1, 7.2.5, and 7.3.2.
Describe Type 4 analyses	Sections 7.3.1 and 7.3.4
Describe deviations from standard methods	Sections 7.2.1 and 7.3.1
Summarize LWD recruitment situations	Section 7.2.2 and 7.2.3
Summarize long-term LWD recruitment prospects	Section 7.2.5
Describe canopy closure situations	Section 7.3.2
Describe confidence in products	Sections 7.2.6 and 7.3.5
Suggest module revisions	Not included

7.2.2 Near-Term LWD Recruitment Potential

The majority (53 percent) of riparian timber stands along fish-bearing waters (Types 1, 2 and 3) in the Acme WAU are "deciduous, young, sparse" (Figure 7-1; Table 7-1). Other deciduous stands account for 35 percent of the stands surveyed, while only 12 percent are mixed or coniferous stands. None of the stands are dominated by large trees; 75 percent are young and the rest are mature. Most stands (63 percent) have a sparse canopy. Consequently, the majority (83 percent) of stands present poor prospects for near-term LWD recruitment (Figure 7-2).

Table 7-1 Riparian stand types encountered on the Acme WAU. "Abundance" is expressed as a percentage of the total bank length of streams surveyed.

RIPARIAN STAND CONDITION	CODE	ABUNDANCE	RECRUITMENT
Deciduous, Young, Sparse	DYS	53.1%	Poor
Deciduous, Young, Dense	DYD	19.7%	Poor
Deciduous, Mature, Dense	DMD	9.3%	Fair
Deciduous, Mature, Sparse	DMS	5.7%	Poor
Mixed, Mature, Sparse	MMS	0.9%	Poor
Mixed, Young, Dense	MYD	0.6%	Poor
Coniferous, Mature, Dense	CMD	6.8%	Good
Coniferous, Mature, Sparse	CMS	2.6%	Fair
Coniferous, Young, Dense	CYD	0.6%	Fair
Coniferous, Young, Sparse	CYS	0.7%	Poor

Most (89 percent) of the fish-bearing streams on the Acme WAU traverse lands presently devoted to agricultural uses (Table 7-2). The 15 RCU's situated in lands devoted to timber production are predominantly (88 percent) forested with mature timber. LWD recruitment prospects are good on 57 percent and fair on 29 percent of these RCU's. Poor LWD recruitment is encountered on RCU's 73 and 74, located in mixed stands along lower McCarty Creek, an area transitional between forest and agricultural lands. Poor recruitment is also encountered on RCU's 112 and 115, which adjoin recent clearcuts on upper Tinling Creek. Under appropriate management, all RCU's presently on forested lands appear capable of supporting "coniferous, old, dense" riparian forests with good LWD recruitment.

On agricultural lands, poor LWD recruitment exists on RCU's 1-7, 10-16, 19, 22-23, 26-27, 30-32, 35-41, 43-52, 55-59, 62-66, 71-72, 75-78, 81-96, and 98-108 (Table 7-3). These streams typically traverse pasture lands and are bordered by narrow bands of hardwood trees. In areas where the forest strip is less than 66 feet wide, the forest canopy is classified as sparse. Since hardwoods decay more rapidly than conifers, these trees cannot contribute high-quality LWD to the streams. Grazing by cattle, frequent disturbance associated with agricultural development, and distance from a conifer seed source combine to keep these stands young and virtually free of conifers. Many of the affected channels have been straightened and LWD removed in the process. Under such a management regime, both in-channel LWD and LWD recruitment prospects are necessarily poor.

Areas of high or moderate near-term LWD recruitment hazard have been assigned to four resource sensitivity areas (RSAs), delineated according to the affected channel types (Section 11). The following table summarizes these RSAs:

RSA	Description
RSA R-1	Reduced LWD recruitment potential is one facet of extensive habitat loss to due landscape changes that have occurred on the floodplain of the South Fork Nooksack River.
RSA R-2	Conversion of forest land to agricultural uses has resulted in loss of riparian forest and removal of in-channel LWD.
RSA R-3	Timber harvest, agricultural conversion and residential development have reduced the potential of riparian forests situated on alluvial fans to provide suitable LWD to affected streams. Loss of these riparian forests has also exacerbated the impacts of debris flows and dam-break floods delivered to these alluvial fans.
RSA R-4	Riparian forest removal associated with former timber harvest has reduced LWD recruitment potential along fish-bearing mountain stream channels.

Table 7-2 Near-term woody debris recruitment potential classified according to land use.

LAND USE	RECRUITMENT POTENTIAL	LENGTH (miles, both sides)	ABUNDANCE
Agriculture	Poor	54.9	80%
Agriculture	Fair	5.8	8%
Agriculture	Good	0.4	1%
Forestry	Poor	1.1	2%
Forestry	Fair	2.2	3%
Forestry	Good	4.3	6%

Table 7-3 Summary of in-channel LWD and LWD recruitment potential for all RCU's.

CHANNEL SEGMENT	RCU	RATING	RECRUITMENT	RF TYPE	LENGTH (mi.)	STREAM TYPE
South Fork Nooksack	1	DYS	Poor		3.0	1
	2	DYD	Poor		2.0	1
	3	DYS	Poor		1.0	1
	4	DYD	Poor		1.0	1
	5	DYD	Poor		1.2	1
	13	DYS	Poor		1.0	1
	14	DYS	Poor		0.8	1
	19	DYD	Poor		0.5	1
	38	DYD	Poor		0.5	1
	39	DYS	Poor		0.7	1
	40	DYS	Poor		0.5	1
	41	DYD	Poor		0.6	1
	51	DYD	Poor		0.3	1
	52	DYS	Poor		0.3	1
	55	DYD	Poor		0.6	1
	56	DYS	Poor		1.0	1
	57	DYS	Poor		0.8	1
	64	DYD	Poor		1.6	1
	65	DYD	Poor		0.3	1
	66	DYS	Poor		1.1	1
	75	DYS	Poor		3.7	1
	76	DYD	Poor		0.7	1
	77	DYS	Poor		0.3	1
	78	DYD	Poor		0.7	1
	93	DYS	Poor		1.6	1
	94	DYD	Poor		0.4	1
	95	DYD	Poor		0.3	1
	117	DMS	Poor		0.3	1
	118	DYD	Poor		0.3	1
	119	MYD	Poor		0.5	1
Black Slough	20	CMD	Good		0.2	3
	21	CMD	Good		0.2	3
	22	DYS	Poor		0.5	3
	23	DYS	Poor		0.5	3
	24	DMD	Fair		0.6	3
	25	DMD	Fair		0.6	3
	26	DYS	Poor	RF4	0.4	3
	27	DYS	Poor	RF4	0.4	3
	28	DMD	Fair	RF4	0.2	3
	29	DMD	Fair	RF4	0.2	3
	31	DYS	Poor		2.4	3
	37	DYS	Poor		2.1	3
	108	DYD	Poor		0.2	3
Black Slough trib.	106	DYS	Poor		0.7	3
	107	DYS	Poor		0.7	3

Caron Road Creek	6	DYS	Poor	RF4	0.7	2+3
	7	DYS	Poor		0.3	2
	8	CYD	Fair		0.2	3
	9	CYD	Fair		0.2	3
	10	DYS	Poor	RF4	0.4	3
	11	DMS	Poor		0.5	2
	12	DMS	Poor		0.5	2
Clipper Ditch	62	DYS	Poor		0.6	3
	63	DYS	Poor		0.6	3
Gravel pit creek	96	DYS	Poor		0.3	3
	97	DMD	Fair		0.3	3
Hardscrabble Creek	58	DYD	Poor	RF4	0.2	3
	59	DYD	Poor	RF4	0.2	3
	60	CMD	Good	RF2	0.2	3
	61	CMD	Good	RF2	0.2	3
Jones Creek	85	DMS	Poor	RF4	0.4	3
	86	DMS	Poor	RF4	0.4	3
Landing Strip Creek	87	DYD	Poor		0.3	3
	88	DYD	Poor		0.3	3
	89	DYS	Poor	RF4	1.0	3
	90	DYS	Poor	RF4	1.0	3
	91	DYD	Poor		0.3	3
	92	DYD	Poor		0.3	3
McCarty Creek	71	DYS	Poor		0.5	3
	72	DYS	Poor	RF4	0.8	3
	73	MMS	Poor	RF4	0.4	3
	74	MMS	Poor		0.2	3
Mile 6.2 trib.	69	CMS	Fair		0.4	3
	70	CMS	Fair		0.4	3
Mosquito Lk. Rd. Ck.	79	DMD	Fair		0.5	3
	80	DMD	Fair		0.5	3
	81	DYS	Poor		0.7	3
	82	DYS	Poor		0.7	3
	83	MYD	Poor		0.2	3
	84	MYD	Poor		0.2	3
Standard Creek	67	CMD	Good	RF2	0.6	3
	68	CMD	Good	RF2	0.6	3
Sygitowicz Creek	53	DMD	Fair	RF4	0.4	3
	54	DMD	Fair	RF4	0.4	3

Tinling Creek	30	DYS	Poor		1.3	3
	32	DYS	Poor		0.6	3
	33	DMD	Fair	RF4	0.3	3
	34	DMD	Fair	RF4	0.3	3
	35	DMS	Poor		0.2	3
	36	DMS	Poor		0.2	3
	110	CMD	Good		1.1	3
	111	CMD	Good		0.9	3
	112	CYS	Poor		0.2	3
	113	CMS	Fair		0.7	3
	114	CMD	Good		0.7	3
	115	CYS	Poor		0.3	3
	116	CMS	Fair		0.3	3
Todd Creek	42	DMD	Fair		0.3	3
	43	DMS	Poor		0.5	3
	44	DYS	Poor	RF3	0.5	3
	45	DYS	Poor	RF3	0.5	3
Todd Creek trib.	46	DMS	Poor		0.3	3
	47	DMS	Poor		0.4	3
	48	DMS	Poor		0.5	3
	49	DYS	Poor		0.3	3
	50	DYS	Poor		0.3	3
Toss Creek	15	DYS	P		0.2	3
	16	DYS	P		0.2	3
	17	DMD	F	RF4	0.8	3
	18	DMD	F	RF4	0.8	3
Van Zandt Creek	98	DYS	Poor		0.2	3
	99	DYS	Poor		0.2	3
	100	DYD	Poor		0.5	3
	101	DYD	Poor		0.5	3
	102	DYS	Poor		0.3	3
	103	DYS	Poor		0.3	3
Van Zandt Ck. trib.	104	DYD	Poor		0.3	3
	105	DYS	Poor		0.3	3
Williams Lake	109	DMD	Fair		0.2	2

7.2.3 Naturally Low LWD Recruitment Sites

No naturally low LWD recruitment sites have been encountered in field surveys. Records of the 1885 land survey indicate that open water wetlands such as beaver ponds and sloughs formerly existed in various locations on the valley bottom, and such sites may have constituted areas of naturally low LWD recruitment. Substantial areas (chiefly within the Black Slough drainage) contain hydric soils (Figure 7-3) that in unmanaged landscapes typically support forests dominated by red alder; such forests may not contribute significant LWD to streams. Nonetheless, notes from the 1885 survey and other historical sources (Jeffcott 1949) report that the valley bottom was thickly forested and included extensive tracts of large conifers, suggesting that areas of naturally low LWD recruitment were few and small.

7.2.4 In-Channel LWD

LWD recruitment potential was compared with existing levels of in-stream LWD for 26 of the RCU's, all but two of which (RCU's 60 and 61) are located on agricultural lands (Table 7-3). In-channel LWD occurs above the target level of two pieces per channel width only in RCU's 44 and 45, representing a total channel length of 0.5 miles. These RCU's have a "sparse, young, deciduous" riparian forest with poor LWD recruitment potential; thus they represent situation RF3 (Figure 8-2). RCU's 60, 61 and 67 represent situation RF2; they have good LWD recruitment potential, but in-channel LWD is below target. The predominant situation is RF4, indicating below-target in-channel LWD and a poor recruitment potential; this situation applies on RCU's 6, 10, 17-18, 26-29, 33-34, 53-54, 58-59, 72-73, 85-86, and 89-90. It was noted during Level 2 surveys that most of the agricultural RCU's appear to have had LWD removed and many of these RCU's have been graded and straightened; thus, situation RF4 probably prevails in most of the agricultural RCU's.

7.2.5 Long-Term LWD Recruitment Potential

RCU's located on lands dedicated to timber production generally have fair or good LWD recruitment potential. All of these lands appear capable of supporting old coniferous forest; thus they have a long-term potential for good LWD recruitment. Most of these RCU's are already dominated by mature conifers, so it is likely that they will be dominated by old conifers within 40 to 70 years, assuming that they are managed to retain a suitable riparian forest buffer as discussed below.

The agricultural lands present a more complex picture (Figure 7-3). These lands are located on the valley bottom. Some are on hydric soils that would normally support a forest dominated by red alder or, if left undisturbed for long enough (more than 100 years), wet-site conifers such as Sitka spruce, western redcedar and western hemlock. Many of these lands were recorded in the 1885 survey as "swamp" (forested wetlands). Survey records indicate that red alder, black cottonwood, bigleaf maple, Sitka spruce, western hemlock, western redcedar and Douglas-fir were all present and sometimes grew large within these forests. Presently, a remnant swamp in the Black Slough area still contains a few old-growth Sitka spruce. It is not possible to determine if these wetland forests would be classified as deciduous or mixed according to criteria set forth in the Manual. If deciduous, they are capable of supporting fair LWD recruitment; if mixed, they could support good LWD recruitment. If riparian zones were planted with appropriate conifers such as Sitka spruce and western redcedar, these areas would probably support a mixed or coniferous forest with good LWD recruitment.

The valley bottom also contains well-drained soils that can support a coniferous forest dominated by Douglas-fir. These soils are chiefly located within the meander belt of the South Fork, an area that contained numerous small slough channels that provided important fish habitat during presettlement times (Section 8.5). These channels are mentioned in notes of the 1885 survey and were mapped in 1938 (channel segment 3 in Figure 6-12). Forest in these areas could support good LWD recruitment in an area of particularly abundant salmonid habitat. There is historical evidence of such a condition; the main stem of the South Fork in this valley formerly contained abundant LWD in the form of channel-spanning logjams (Morse 1883, Jeffcott 1949).

In view of historical development trends in the valley of the South Fork, it is unlikely that the valley bottom will return to a presettlement condition. However, substantial land use changes will be required if the area is to regain a significant fraction of the quantity and quality of anadromous fish habitat that existed during presettlement times. The primary focus of such a habitat restoration project would be to allow the channel of the South Fork to regain a sinuous, unconfined channel containing abundant LWD and bordered by an active floodplain containing numerous slough channels. Development of such a channel is a prerequisite to resolution of LWD and stream temperature problems that presently exist in the South Fork.

The goal of channel and floodplain restoration could be achieved by withdrawing confinement structures such as dikes to the edge of the river's former meander belt. This area is dominated by sandy soils (Figure 7-3) but is also delineated fairly accurately by the 50-year floodplain (Figure 9-1). Such a management regime would remove from cultivation a band approximately 1/2 mile wide through the length of the WAU and would permit re-establishment of a large portion of the presettlement fishery habitat in the WAU. If adequate riparian buffers were provided, the floodplain would support a conifer-dominated riparian forest, ensuring that a good supply of LWD could be maintained.

Slough channels adjoining an unconfined main channel provide some of the most important salmonid spawning and rearing habitat (Sedell et al. 1982). Over 86% of these channels (Channel segment 3; see Section 6.6.2) have been eliminated within the WAU since presettlement times (channel module). Restoration of slough channels would produce far greater enhancement of fish habitat than would any improvement of the present, very limited amount of fish habitat. New slough channels would develop over the long term as a consequence of the development of an unconfined stream channel (Fetherston 1995; Swanson and Lienkamper 1982). The process might be accelerated by active management to reopen remnant slough channels identified in the course of this analysis (Channel Segment 3, Figure 6-12). Provision of an adequate riparian buffer would ensure a good supply of LWD to these channels.

Finally, the floodplain and slough channels must be bordered by a riparian forest with buffer widths adequate to ensure adequate riparian function on the South Fork and slough channels. Large LWD accumulations in rivers, often in the form of logjams, produce a complex pool-and-bar channel topography that provides for regeneration of riparian forest, periodically creates new slough channels, and generally provides abundant salmonid habitat (Abbe 1995; Botkin et al. 1994; Fetherston 1995; Sedell and Swanson 1984; Swanson and Lienkamper 1982). LWD in slough channels helps to provide bank stabilization, sediment trapping, and other functions similar to the role of LWD in mountain streams. The following criteria help to determine the desired width of LWD recruitment buffers in floodplains:

1. Critical pieces of LWD in large rivers tend to be provided by large trees deposited into the stream with intact rootwads (Abbe 1995).

2. A buffer width of at least one mature tree height is required to preserve full LWD recruitment function (Cederholm 1994). Such a buffer width must be measured from the edge of the active riparian zone. In the case of the South Fork this will include at a minimum the two-year floodplain and more conservatively, most of the active meander belt.

3. The functional riparian buffer on a large stream must contain large LWD, such as is only provided by a late-successional forest (Bilby and Ward 1989). There should be no harvest permitted within this buffer, both to permit the growth of large trees and to reduce the likelihood of catastrophic windthrow within the buffer (Andrus and Froelich 1993, Harris 1989).

7.2.6 LWD Assessment: Confidence in Work Products

The overall level of confidence in LWD recruitment analysis is high for the following reasons:

1. Aerial photographs from 1991 were used. Previous watershed riparian aerial reviews have provided a high level of accuracy.

2. All indeterminate reaches were field-verified, as were many poor recruitment reaches identified from the aerial photograph assessment. Representative fair and good recruitment reaches were also verified.

3. Field assessments included collection of data not specifically required in the module which assisted in final interpretations of near- and long-term LWD recruitment potential. Such data included qualitative observations such as land use (agricultural or timber production), evidence of human manipulation of the channel, and presence of wetland habitat.

4. Soil surveys and historical writings, maps and airphotos were used to assess presettlement forest and channel condition and thereby to determine the potential outcome of long-term management for optimum LWD recruitment.

7.3 STREAM TEMPERATURE

Salmonids require cool and stable water temperatures, and riparian shade is an important factor in determining stream water temperature (Brown and Krygier 1970). However, additional factors such as groundwater exchange, channel morphology, and state of the hyporheic zone can also influence stream temperature, particularly in relatively large streams. Therefore this analysis will address the issue of stream temperature in the South Fork, despite the fact that in most of the WAU, the river has a low-flow width of more than 100 feet.

7.3.1 Methods

The canopy closure/stream temperature assessment boundaries were determined according to the following criteria:

1. All surface waters were identified as Class A, as determined by the Washington State Department of Ecology.

2. We examined all Type 1 to 3 waters and all Type 4 non-fish bearing streams that contribute at least 20 percent of the flow of Type 1 to 3 fish bearing streams. Since the temperature of small streams is assumed to be at equilibrium after the stream has traveled more than 1000 feet under a uniform canopy (Caldwell et al. 1991), only the lower 1000 feet of these Type 4 streams was examined.

3. Target (minimum acceptable) shade values were determined according to elevation as specified in the Manual (Table 7-2).

Potential temperature problem areas were identified by comparing target shade values with estimated existing shade. Stream reaches where existing riparian shade is less than the target value are delineated as areas where stream temperatures are likely to exceed state water quality standards. Field investigations were made in areas where aerial photo assessments indicated indeterminate or below-target shade. In these areas, percent shade was measured using a spherical densiometer. Results of these investigations are included in Appendix 7-2.

This analysis deviated from the protocols set forth in version 2.1 of the Manual in two ways:

1. Stream temperature is evaluated for the South Fork Nooksack River, despite the fact that most of the river in the WAU has a low-flow width of more than 100 feet. This was done because historical records indicate that the South Fork did not experience high temperatures during presettlement times, suggesting that human interventions have caused the high summer temperatures presently encountered in this stream.

2. Results are not classified according to channel segment type. This was done because the primary factor influencing riparian shade is not channel type, but land use. Nearly all agricultural lands (96 percent) have below-target shade and include most of channel segments 1, 2, 3 and 4. Sixty-seven percent of forested lands have within-target shade and include all of channel segment 7. In channel segments 5 and 6, forested reaches tend to have adequate shade and agricultural reaches tend to have inadequate shade. Thus, classification of shade levels according to channel segment would present a misleading picture of the distribution and causes of below-target riparian shading.

7.3.2 Results

Existing and target shade levels were estimated for 44 Riparian Shade Units (RSU's) in the Acme WAU (Figure 7-4). Target riparian shade levels based on elevation are nearly all greater than 70 percent, as the great majority of fish bearing waters occur on or near the floodplain of the South Fork Nooksack River at elevations of 230 to 300 feet. Existing shade levels determined from aerial photographs and on-site densiometer measurements range from zero to more than 90 percent. Shade levels are greater than 70 percent on only 13 percent of the surveyed waters, while 64 percent of the streams have less than 20 percent shade.

Nooksack River

Figure 7-4 shows riparian shade impact ratings for the Acme WAU. Out of 40.1 miles of surveyed streams, 15.4 miles (38 percent) are located along the Nooksack River or South Fork Nooksack mainstem in RSU's 1, 2 and 3. Instrumental temperature data are reported in detail in Section 10.4. Two temperature measurement stations were maintained on the Nooksack River in the course of this analysis and these recorded maximum temperatures of 18 degrees and 17 degrees Celsius. These are within the allowable maximum temperature of 18 degrees Celsius for Class A waters. The South Fork is a substantially warmer stream; the one recording station, located where the river enters the WAU, recorded a maximum temperature of 21.5 degrees Celsius. These results are consistent with the findings of Neff (1993a, 1993b), who found a maximum water temperature of 24 degrees Celsius at River Mile 19 and a maximum of 23.9 degrees Celsius at Acme based on short-term data collected during the summer of 1992. Historical sources (Jeffcott 1949) report that the South Fork had remarkably cold summer water temperatures ca. 1885, despite the fact that much of the stream was more than 100 feet wide and thus was unlikely to receive significant shade from riparian forests. It therefore seems likely that the present high water temperatures found in the South Fork can be attributed to land use changes in the basin since 1885. One such change is land clearance due to both forest harvest and agricultural development, processes that have occurred both within the WAU and within the eighty percent of the South Fork watershed that lies upstream from the WAU. These factors have reduced riparian shade along the South Fork and along many of its tributaries, increasing water temperatures via increased exposure to solar insolation. Former low water temperatures may also be attributed to a variety of factors that would have contributed to increased rates of exchange between stream waters and groundwater, a process that may significantly affect water temperatures in large streams throughout the Pacific Northwest (Sedell and Swanson 1984). These factors include:

1. Abundant in-channel LWD contributed to an abundance of deep pools (Nooksack Spring Chinook Technical Group 1987). Groundwater exchange with such pools may have provided significant cooling (Keller and Hofstra 1982).

2. A complex channel, in places divided or strongly meandering, likely experienced increased groundwater exchange due to flow under gravel bars or across meander bends, processes recently described on the Queets River in the Olympic Peninsula (Edwards 1995).

3. Removal of over 95 percent of presettlement-era slough channels has caused a great reduction in the ratio of stream bank length to stream area within the floodplain, reducing flow between groundwater and channels.

4. In presettlement times the river banks were densely forested; many areas contained sloughs or were described as swamps by early surveyors. These factors indicate that groundwater levels were formerly higher. Cutting of floodplain forests and drainage of floodplain wetlands has lowered the water table, locally reducing the hydraulic head that would drive groundwater into stream channels. Removal of these wetlands may particularly affect stream hydrology during the summer low flow period.

Processes such as dike construction, LWD removal, forest clearing, and wetland drainage have strongly influenced the hydrologic regime in the floodplain of the South Fork. It seems unlikely that any effort to remediate the present high summer temperatures observed in the South Fork will succeed if stream shading is viewed as the only cause of those high temperatures. Clearly, channel morphology, floodplain vegetation, associated wetlands, slough channels and groundwater hydrology must also be considered. A proposal to mitigate salmonid habitat problems within the floodplain of the South Fork has been presented above. The provisions of that proposal would not only provide adequate LWD, but would largely resolve the above-mentioned groundwater problems and would provide adequate shade to slough channels and other fish-bearing waters on the South Fork floodplain.

Other Fish bearing Waters (Types 2 and 3)

Of the 24.7 miles of surveyed streams that are less than 100 feet wide, 20.5 miles (83 percent) are Type 2 or 3 waters (Table 7-4). Approximately 15.9 miles (78 percent) of these waters do not meet target shade requirements. The majority (80 percent, 16.4 miles) of the fish bearing streams are located in lands dominated by agricultural uses. The remaining streams (20 percent, 4.1 miles) are located in lands devoted to forest management or mixed forest and agricultural uses. On agricultural lands, 15.1 miles (92 percent) do not meet target shade values. This includes RSU's 6-9, 12-14, 16, 18, 20, 28-29, 31-32, 34-36, 38-39, and 41-43. On forested lands, 0.8 miles (20 percent) do not meet target shade values. This includes RSU 23 (Standard Creek) and RSU 26 (McCarty Creek). Most RSU's that do not meet target shade values consist of young deciduous stands forming narrow bands of forest along the streams. In this situation shade values of 0-20 percent are typical.

Areas of high canopy closure hazard have been assigned to one resource sensitivity area (RSA R-5) covering all channel types (Section 11). Three temperature recording stations were located on Type 3 waters (see Figure 9-1 and Table 9-5). One was located at the lower edge of RSU 17, a reach where observed shade exceeded the target value of 70 percent. This station recorded a maximum temperature of 21 degrees Celsius, well above the Class A maximum of 18 degrees. A second station, located within RSU 21, recorded a maximum temperature of 17 degrees. This RSU had measured shade of 58 percent, slightly below the target of 70 percent. A third station, located within RSU 27, recorded a maximum temperature of 17.5 degrees. This RSU had shade of over 90 percent, well above the 70 percent target.

In general, riparian shade is adequate in forested sections of the WAU. The exception is in areas recently subject to timber harvest, where shade is not adequate but prescriptions calling for establishment of a streamside vegetation buffer are likely to permit development of adequate shade. The situation is more complex in the agricultural lands that cover the valley bottom. In these areas most fish-bearing tributary streams have inadequate riparian shade but may also experience relatively warm water temperatures due to low flows and wide, shallow channels. As noted above, these problems must be addressed in the context of a variety of processes causing warm stream temperatures in the floodplain of the South Fork. Restoration

Table 7-4 Lengths of surveyed streams in categories of particular interest. "Shaded" indicates length of streams having adequate shade.

WATER TYPE	LENGTH		SHADED LENGTH	
	MILES	PERCENT	MILES	PERCENT
All surveyed streams	40.1	100	6.6	16
Type 1 (all are >100 feet wide)	15.4	40	0	0
Type 2 and 3 agricultural	16.4	43	1.3	3
Type 2 and 3 forest	4.1	10	3.3	8
Type 2 and 3 subtotal	20.5	51	4.6	11
Type 4 agricultural	1.9	5	0.2	1
Type 4 forest	2.3	6	1.8	4
Type 4 subtotal	4.2	10	2.0	5

of an unconfined channel within the meander belt of the South Fork and protection by an adequate riparian buffer on fish-bearing streams will largely resolve these problems.

7.3.3 Dominant Fish Use Zones

The mainstem of the South Fork is used as summer holding habitat by migratory fall chinook. This entire area is a zone of potential temperature concern. Most of the tributary streams on the floodplain of the South Fork (channel segment 4) and the lower part of McCarty Creek (channel segments 5 and 6), are used as winter rearing habitat by coho and are in areas of potential temperature concern. Similarly, fish-bearing streams on the alluvial fans on the west side of the valley (channel segments 5 and 6) provide winter steelhead spawning habitat and are in areas of potential temperature concern. Although water temperatures are not likely to exceed water quality standards during the winter months, the low levels of shade on these streams are likely to produce elevated water temperatures and increased diurnal temperature fluctuations that may affect rate and timing of such processes as egg development, alevin growth and emergence, and fry growth and survival (Beschta et al 1987, Hartman et al 1987).

7.3.4 Non-Fish Bearing Waters (Type 4)

Selected 1,000-foot channel segments immediately upstream of Type 1 to 3 waters were evaluated for existing and target shade. These streams have a total length of 4.2 miles, of which 2.2 miles (52 percent) have inadequate shade and represent potential areas of temperature concern. RSU's 11-12, 28-30 and 38 have a cumulative length of 1.2 miles and are located on agricultural lands; they have insufficient shade (0-20 percent) because they are bordered by narrow bands of young, deciduous forest. RSU's 37 and 43 are also on agricultural lands, but due to the presence of a relatively dense deciduous forest they have somewhat greater shade (20-70 percent). RSU's 21, 23 and 26, located on forested lands, have a cumulative length of 0.6 miles and have moderate shade (about 50 percent) that is still below the target value of 70 percent. A riparian buffer width of 100 feet is widely regarded as necessary to ensure adequate riparian shade (Brazier and Brown 1973, Steinblums et al. 1984). The use of such a buffer is recommended on RSU's 10-12, 15, 17, 19, 21-30, 33, 37, 38, 40, 43 and 44.

7.4. Shade assessment: Confidence in Work Products

The overall level of confidence in the analysis is moderate to high for the following reasons:

- Field measurements show agreement between aerial photograph-based and field-based estimates of riparian shade.

- All indeterminate reaches were field-verified. Not all reaches were field-verified, and riparian shade may have been altered on some of these reaches since the aerial photography was performed. Conditions on some reaches may have changed since the field surveys were conducted.

- Data collected on field visits and by review of historical literature greatly aided assessment of management-related impacts on stream temperature. Such evaluations highlighted the importance of nonshade factors such as manipulation of the mainstem South Fork Nooksack channel and drainage of wetlands in the South Fork floodplain.

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APPENDIX 7-1

SUMMARY OF ACME WATERSHED RIPARIAN CONDITION UNITS

Summary of Level 2 Findings

RCU's 8 and 9: CYD, "Fair"
These RCU's have some mature deciduous trees (alder and cherry), but the riparian zone is dominated by a young Douglas-fir plantation. Natural regeneration is predominantly hardwoods, suggesting that management intervention is needed to ensure a conifer LWD supply. Depending on site management, long-term LWD input prospects are "good."

RCU's 11 and 12: DMS, "Poor"
Land use is agricultural. Mature trees are mainly north of the bridge; area to the south is a wetland. Regeneration is dominated by cottonwood and is retarded by grazing. Due to agricultural management, prospect for LWD input is "poor" both for the short and long terms.

RCU's 17 and 18: "DMD", "Fair"
Land use is agricultural. Much of the area is wetland. Forest is hardwood-dominated with some residual Douglas-fir, redcedar and hemlock; regeneration is primarily hardwoods. Residual trees indicate that this forest can support a population of large conifers. Short-term LWD recruitment prospects continue to be "fair", but prescriptive management such as selective hardwood logging and planting of cedars could produce "good" LWD inputs in the long term.

RCU's 24 and 25: DMD, "Fair"
These RCU's adjoin the Black Slough, a swamp on the valley bottom. Stumps, snags and a few residual Sitka spruce indicate that the area once supported an old-growth conifer forest, at which time the Slough likely contained abundant LWD. The area was logged and is presently surrounded by agricultural land.

RCU's 33 and 34: DMD, "Poor"
These RCU's are on the valley bottom in agricultural land. As with many of the "Type 3" streams on these bottom lands, the stream was dry at survey time. No LWD was seen in the stream; presumably it is removed by the landowner for flood control purposes. Evidence elsewhere on the valley floor (see RCU's 24 and 25) suggests that the area can sustain large conifers with ample LWD production, but given the stream's present agricultural management, prospects for near- and long-term LWD input warrant a "poor" rating despite a dense cover of mature hardwoods in the units.

RCU's 35 and 36: DMS, "Poor"
These units resemble and adjoin RCU's 33 and 34, but hardwoods are restricted to a relatively narrow strip along the stream, so the overall canopy cover is sparse instead of dense. LWD input potential is clearly "poor."

RCU 42: DMD, "Fair"
Agricultural land, surveyed from adjacent road. The overstory is dominated by large cottonwoods, which tend to experience very rapid decay. Many of the soils are likely hydric. Assuming continued agricultural management, LWD input potentials for both short and long term are intermediate between "poor" and "fair."

RCU's 43, 46, 47, and 48: DMS, "Poor"
Situation same as for RCU 42, except with lower tree density.
RCU's 53 and 54: DMD, "Fair"
Environment is intermediate between agricultural and forested, although RCU's are on valley bottom. Canopy is dominated by bigleaf maple and black cottonwood, with red alder and cottonwood regeneration. The low decay resistance of cottonwood places these units at the low end of a "fair" LWD input a potential. Short-term LWD recruitment potential is also "fair", and prescriptive management to introduce conifers would be needed to achieve "good" LWD input potential in the long term. Note that this creek has a history of recent debris torrents.

RCU's 58 and 59: DYD, "Poor"
Large bigleaf maple and occasional conifers grow on the slopes outside of the riparian zone. The upper end of the unit is forested, while the lower end is agricultural. Short-term prospects are for continued "young" forest status (average DBH's are presently 2 to 5 inches); over the long term a mature hardwood forest might develop, while prescriptive management would be needed to develop a coniferous forest in a ca. 100-year time frame.

RCU's 71 and 72: DYD, "Poor"
These units are on the valley bottom in agricultural lands and are dominated by varying widths (sometimes less than 66 feet, usually more) of young hardwoods. The associated stream has been graded and channelized. Although these valley bottomlands are capable of sustaining a forest of large, dense conifers, such a forest will not exist here as long as the lands experience primarily agricultural management. Prospects for LWD inputs are therefore "poor" both for the short and long term.

RCU's 85 and 86: DMS, "Poor"
The streambed in these units was dry at survey time. The units are on agricultural land near the town center of Acme and the stream has been channelized for flood control. As on units 71 and 72, this land use pattern precludes significant LWD inputs for both the short and long term, resulting in a "poor" rating.

APPENDIX 7-2

SUMMARY OF ACME WATERSHED RIPARIAN SHADE UNITS

Note: Mainstem wetted width exceeds 100 feet (2.34 mm on 1:13 000 airphotos) on RSU1, RSU2 and >90% of RSU3. Indeterminate calls involve streams with fairly constant shade, but variable shade requirements -- such streams will be adequately shaded in their upper reach, inadequately in their lower reach.

Summary of Field Investigation Findings

Nearly all of the indeterminate initial calls on shade involved streams in the forested portion of the watershed. These streams occur on the steep valley walls and typically change from Type 3 to Type 4 streams near the valley wall/floor transition. Minimum shade requirements drop rapidly as elevation increases from 440 feet (slightly above the valley floor) to 1960 feet (near the ridgecrest), so that on many streams minimum shade requirements fell from >70% to <20% within the space of a mile or two. Such streams were commonly out of compliance in their lower reach (only the lowermost 1000' of a Type 4 stream is considered in this analysis). Paradoxically, many streams were flowing and cold in mature forest on the valley walls, but sank away into dry streambeds when they reached the valley floor.

RSU 21: Channel dry for lowermost 200'. Channel bedrock-controlled, bordered by mature conifers on N and mature hardwoods on S. Average shade 58%.

RSU 22: Lowermost stream section (0-300') dry. Channel and overstory conditions quite variable, but shade consistently high -- average 78%.

RSU 27: Survey near valley bottom finds dry stream in very dense brush, but shade is >70% and in many areas >90%.